Imaging Transitional Disks with TMT: Lessons Learned from the SEEDS Survey

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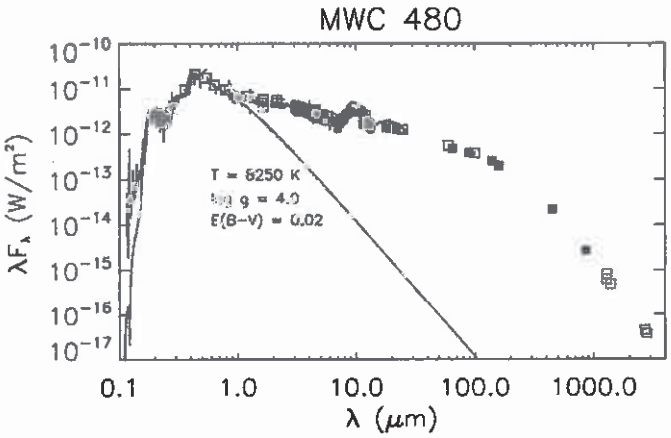
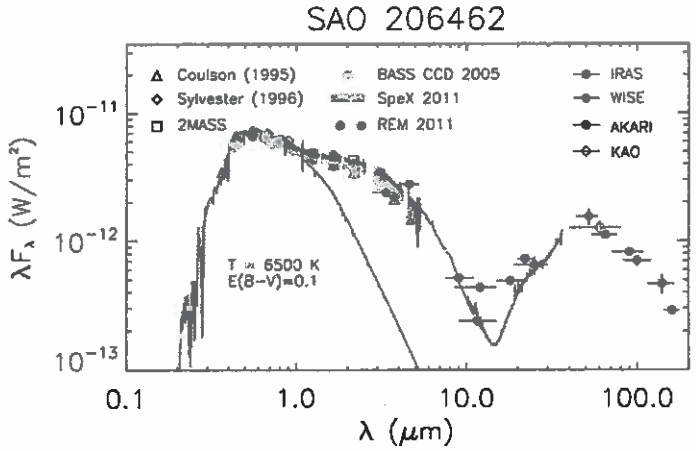
IR SEDS and Imagery for Herbig stars

- HAe stars have 2 distinct types of spectral energy distributions (Meeus et al. 2001; Acke & van den Ancker 04).
- Group II – power law to 200 microns – interpreted as disks with grain growth and settling -Dullemond & Dominik 2004a,b
- Group I fit as power law + BB (Meeus et al. 2001), historically interpreted as flared disks
- Early HST data found scattered light detections were more common (55%), but not universal for group I, and non-detections more common for group II, but again not universal.

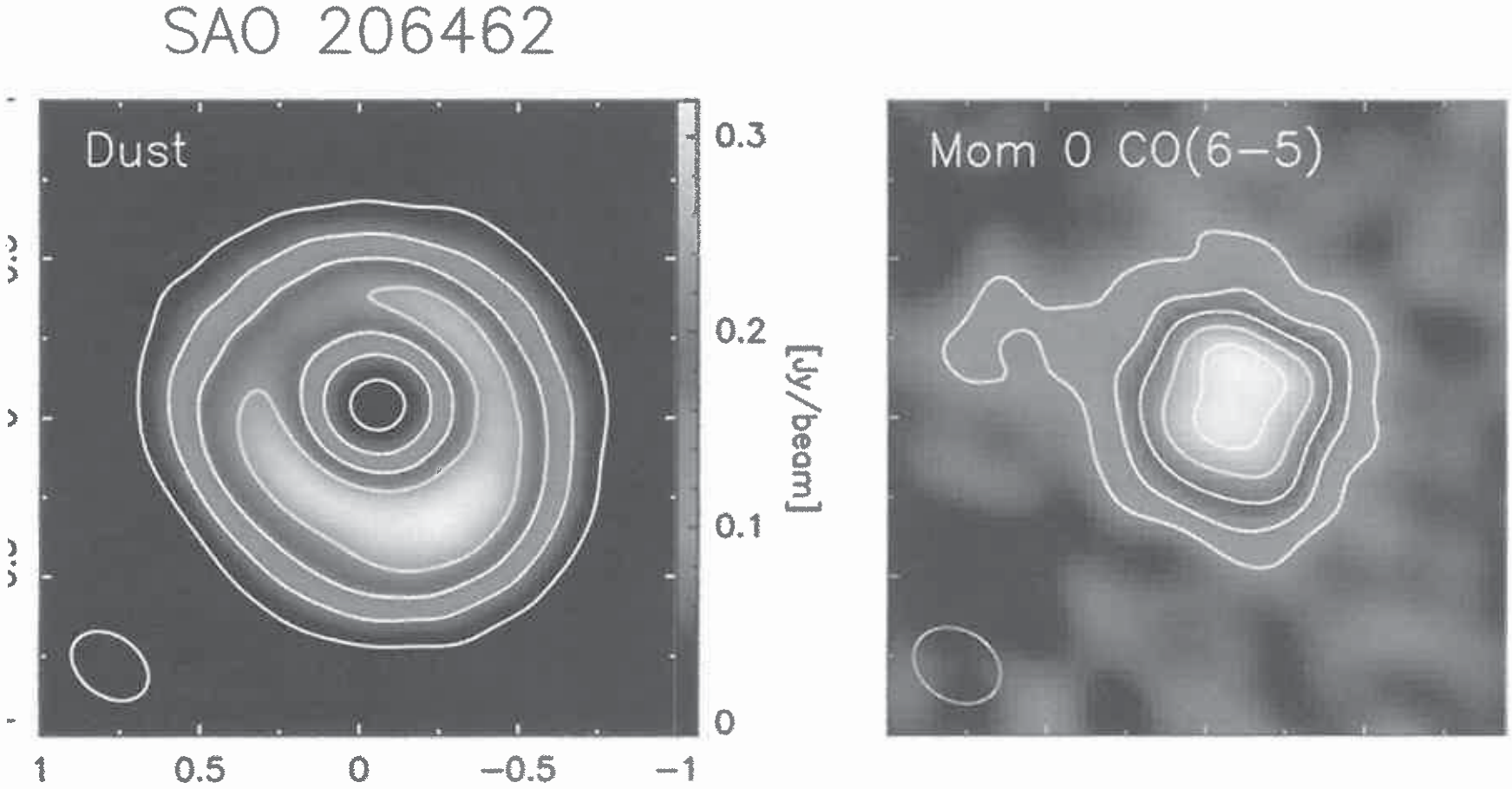




Are Meeus I Disks the missing Herbig Transitional Disks?

- Suggested to be flared disks (Meeus et al. 2001) HST detections tend to have radial SB profiles for the outer disk proportional to r^{-3}. Typical of wedge not flared disks.
- Honda et al. (2012) suggest that these are transitional disks, and specificially ones with inner disk components (pre-transitional in notation of Espaillat et al. (2010).
- Mid-IR data favor interpretation as transitional disks (Maaskant et al. 2013).
- TD defined as having distinctive SED dip, cavities in sub-mm continuum, and associated gas structure…

ALMA data reveal...



Perez et al. 2014

HiCIAO's view

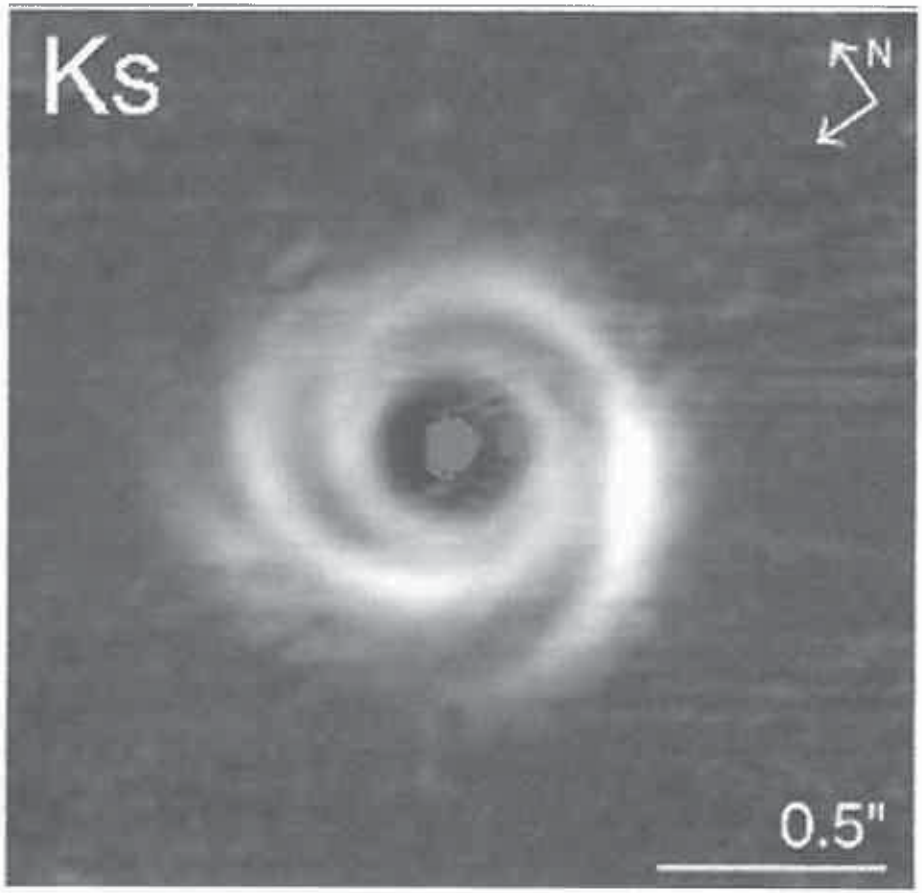
- material in region of SMA & ALMA gap
- disk is not ~circular in Scattered light
- trailing spiral arms

Muto et al. 2012

NIR Gap interior to 0.2”

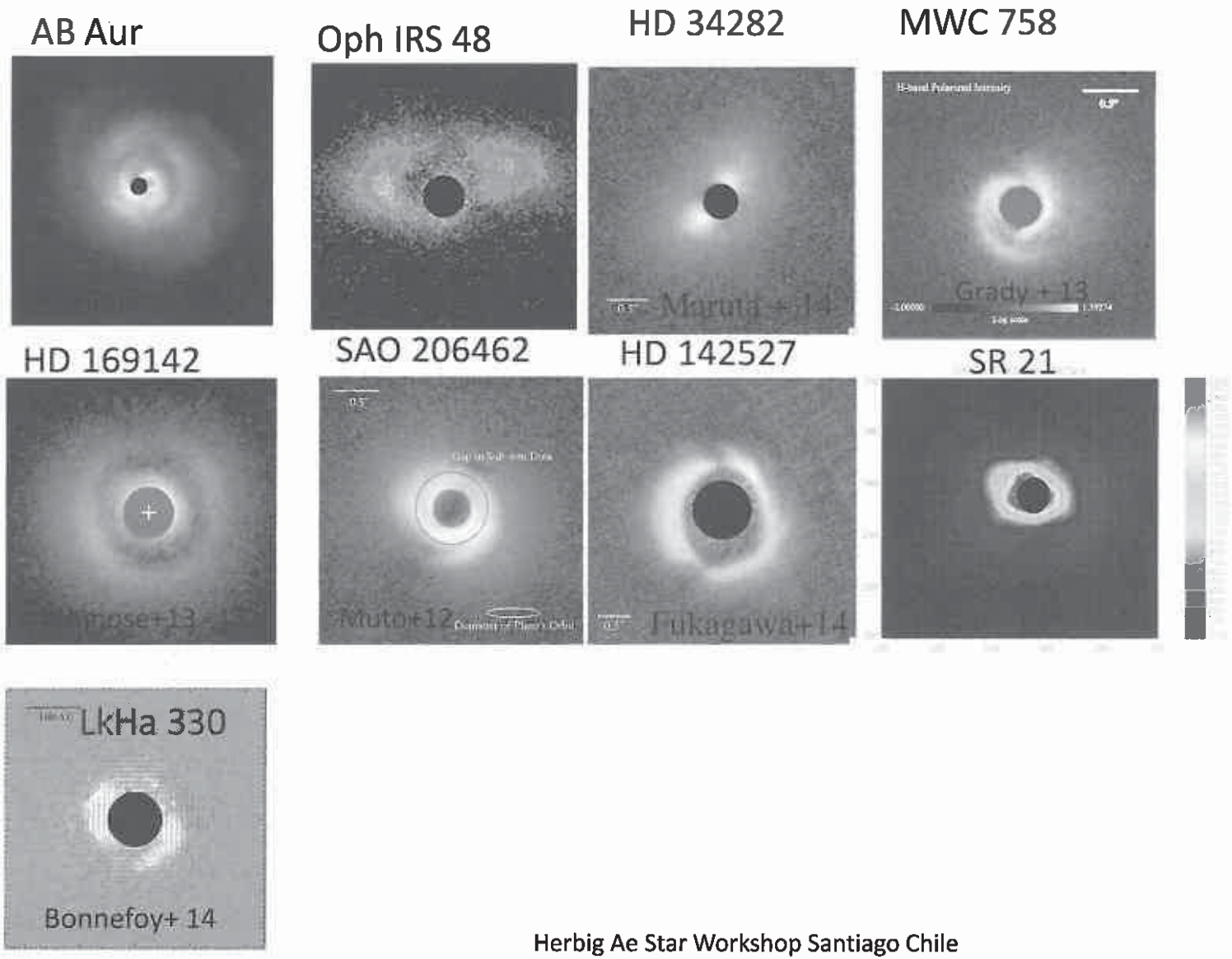
IWA matters…

- Smaller IWA of NaCo
- Reveals gap in small
- Dust ~ same size as
- CO gap (Perez et al.
- 2014)



Garufi et al. 2013

SAO 206462 is not unique



Mechanisms

- Grain growth and settling – would put sub-mm continuum in region of NIR gap – NOT SEEN
- Photoevaporation: hard to achieve for systems with inner, optically thick dust belts, cannot produce disks with pericenter offsets
- Dynamical sculpting by a companion: required for dust trap mechanism to work; can produce pericenter offsets, and crisp edges to NIR dust and sub-mm gas disks.

Meeus I disks are Diverse

- HiCIAO data confirm some HST non-detections are due to angular size of disk (HD 34282, HD 179218),
- NIR PI detection rate is at least 92% and may reach 100%
- Hashimoto (13) has classifiedT Tauri transitional disks into featureless with single SB powerlaw, broken powerlaw, and gapped disks. For the HAes, featureless disks:~ 25% of sample – predominantly more distant objects
- Gapped disks visible in NIR – 44% of HiCIAO sample ↑ ↓ as IWA
- Broken powerlaw systems: 0 hard to find, given other structure
- 45% have spiral arms/features at some wavelengths – may rise with higher contrast provided by extreme AO systems
- 35% of the HiCIAO sample have eccentric gaps

Outer Disk Partial Shadowing

- Demonstrated for SAO 206462, MWC 758 and now HD 142527 (Christiaens +14)
- Indicates that the arm/shadowing structures are at high altitude: for HD 142527 wall H/R=0.42, in outer disk more like 0.1
- Optically thick = cast shadows
- May account for some of the prior HST non-detections (MWC 758 with STIS)
- Can't assume that shape of disk in scattered-light imagery reliably informs on geometry

Complicating Factors

- Sub-mm continuum shows where dust mass is concentrated, but not full extent of dust disk
- NIR continuum subject to asymmetric shadowing, complicates measurement of inclination, outer radius, etc.
- Shadowing may produce time-dependent chemistry (or asymmetric detection of species) in disk
- May need multiple measures of a disk's properties in dust and gas

T Tauri transitional disks

- R, I magnitudes too faint for extreme AO on 8m class telescopes – need LGS
- Also likely to host dust traps – offset in inner radius SMA and NIR dust observed PDS 70 (Hashimoto et al. 2014)
- Spiral arms not found except for early-type T Tauri stars – yet – observational selection effect
- Disks are dynamically colder (h/r~0.05) so any arms would be more tightly wound, needing resolution and image stability TMT should produce.
- With LGS capability of NFIRA0S should produce imagery for T Tau transitional disks comparable to Herbig Ae disks with 8m extreme AO systems. Survey should be a priority for early in TMT lifetime.

Summary

- NIR polarized light imagery of disks has revealed remarkable diversity in Herbig Ae disks and allowed us to identify the Meeus Group I disks as transitional (mostly pre-transitional) disks
- Similar data to that starting to come from extreme AO systems on 8m-class telescopes should be feasible for T Tauri transitional disks early in TMT operations.